Ecologically Based Systems Management (EBSM)

The Snake River - Palisades Dam to Henrys Fork

Final Report
U.S. Bureau of Reclamation
Boise, Idaho

by

F. Richard Hauer
Mark S. Lorang
Diane Whited
and
Phil Matson

Flathead Lake Biological Station[1]
The University of Montana
311 Bio Station Lane
Polson, MT 59860-9659

OPEN FILE REPORT
183-04

[1] Division of Biological Sciences
The University of Montana

April 15, 2004

Citation: Hauer, F. R., M. S. Lorang, D. Whited, and P.Matson. 2004. Ecologically Based Systems Management: the Snake River - Palisades Dam to Henrys Fork. Final Report to U.S Bureau of Reclamation, Boise, Idaho. Flathead Lake Biological Station, Division of Biological Sciences, The University of Montana, Polson, Montana. pp. 133.

INTRODUCTION

Policy Background

Major U.S. federal legislation governs the requirement that our freshwater ecosystems be restored where degraded and/or maintained to meet their designated use. For example, the objective of the Federal Clean Water Act (CWA) is…… "to restore and maintain the chemical, physical and biological integrity of the Nation's waters" [Sec. 101(a)]. The Interim Goal for Aquatic Life *(protection & propagation)* [Sec. 101(a)(2)] states; "It is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife and recreation in and on the water..."

The U.S. Bureau of Reclamation (Reclamation) initiated a Snake River Resources Review (SR^3) in 1995 to "seek the best way to make decisions about operating the Snake River system while incorporating the many concerns, interests and voices dependent on the Snake River" and to "maintain the health of the Snake River without violating contractual obligations and state water law." The goal of SR^3 was to incorporate credible information into a decision support system (DSS) for use in system-wide trade-off analysis related to water management. After review of existing information, it was determined that the information was not sufficient to credibly determine the relationship between river flow and reservoir storage/elevations and aquatic resources.

In 2001, Reclamation sought assistance from Flathead Lake Biological Station (FLBS) in the development of concept, data acquisition, and management approach for a DSS that would meet the objectives of SR^3. Herein, we present an Ecologically Based System Management information and decision support system, which provides a link between system management and the ecological conditions on which aquatic resources depend. These data will be used to inform system operations and may be used in responding to the Endangered Species Act, Clean Water Act, or other system operating constraints.

Study Rationale and the Importance of Floodplains

Reclamation and other federal, state, and tribal agencies have made, and will continue to make, very large financial and human resource investments in the restoration of rivers throughout the western USA. Historically, restoration has focused on fisheries as the most widely and easily recognized aquatic resource to be impacted by human induced stressors of river resources. Unfortunately, the history of river restoration, and indeed most ecological restoration both aquatic and terrestrial, is largely fraught with ineffectual attempts directed at the wrong spatial scale (see Kershner 1997). Indeed, efforts have typically been oriented toward site-specific projects with small spatial contexts (e.g., a few hundred meters of stream length) or with single, narrowly defined objectives confined to a specific species that may be threatened-endangered or of sport or commercial interest (e.g., bull trout, Ute Ladies Tress orchid). These strategies have generally not worked effectively, in part, because they do not integrate the full range of ecosystem scale structural variation or the ecological processes that are necessary to provide the range of life cycle, habitat, or physiological requirements of species dependant on natural river processes (e.g., fishes, aquatic food webs, riparian vegetation)s. Indeed, the nature of ecological problems in rivers that are regulated by dams, diversions and geomorphic change (as is the river in the study area of this report) are primarily manifest at ecosystem levels of organization requiring landscape scale solutions affecting riverine structure and function (Hauer et al. 2003).

In the research presented herein, we have focused our efforts on floodplain reaches along the longitudinal gradient of the Snake River immediately below Palisades Dam to the confluence with the Henrys Fork. We have taken this approach because large alluvial floodplains of gravel-bed rivers throughout the West are the focal points of biological complexity and productivity of both plants and animals. River scientists have known for over a decade that system organization and complexity is maximized on unconfined (i.e., floodplain) reaches compared to confined (i.e., canyon or geomorphically constrained) river reaches (Gregory et al. 1991, Stanford and Ward 1993). Under natural conditions, biodiversity and bioproduction are highest on the expansive floodplains for both aquatic and terrestrial biotic assemblages (Hutto and Young 2002, Pepin and Hauer 2002, Mouw and Alaback 2003, Harner and Stanford 2003). At multiple spatial and temporal scales the biophysical linkages that characterize the natural, high-function floodplains of the pre-settlement Snake River Basin were critical to the sustained and highly complex vegetation, fish, amphibian, bird and mammalian populations found throughout the basin in the early 1800's.

Although there are many competing interests for the water and aquatic resources of the Snake River that will likely continue to impinge on the ecological attributes of the system; ecological integrity (Karr and Chu 1989) as specified by the US Federal Clean Water Act sets the "benchmark" and thus the target condition for restoration. This is our goal in establishing the criteria needed for an operational Ecologically Based System Management.

The Shifting Habitat Mosaic - Hydrologic and Geomorphic Variation

The floodplains of the northern Rocky Mountains encompass a wide array of habitat types associated with the magnitude, frequency and duration of flooding. Floodplains may be expansive or narrow. The porosity of these bed sediments in unconfined river reaches facilitates strong groundwater – surface water interactions and rapid exchange between the channel and the subsurface flow of river-derived water. This hyporheic (*hypo* = under; *rheic* = river) zone of gravel-bed sediment (Figure 1) has been shown to extend as much as 10m in depth and hundreds of meters laterally across expansive western floodplains (Stanford and Ward 1988). The habitats, both on the surface and within the substratum, shift from one place to another in a dynamic mosaic mediated by the interaction between flooding, the generation of stream power, and the supply of sediment. River floodplains are constantly modified by erosion deposition and channel avulsion processes. These fluvial geomorphic processes lead to the destruction of old habitats and the development of new habitats in a spatially and temporally dynamic fashion referred to as a Shifting Habitat Mosaic (Stanford et al. 2001). The SHM is composed of habitats, ecotones, and gradients that cycle nutrients and possess biotic distributions that experience change through the forces associated with fundamental fluvial processes. Features reflecting the legacy of cut and fill alluviation (e.g., flood channels, springbrooks, scour pools, oxbows, wetland rills) may be present on young (i.e., regularly scoured channels) to very old surfaces (i.e., abandoned flood channels among the various forest stands) (Figure 2).

Flooding, geomorphic change resulting from cut and fill alluviation, and subsequent succession of the floodplain vegetation, continually transform the SHM. Development and long-term successional patterns of riparian vegetation are determined, to a large degree, by the type and relative stability of the various floodplain surfaces. For example, the dynamics of cottonwood (*Populus spp.*) and willow (*Salix spp.*) reflect both the legacy of flooding and the frequent exposure of new surfaces of the SHM. Several studies from across western North America have revealed progressive declines in the extent and health of riparian cottonwood

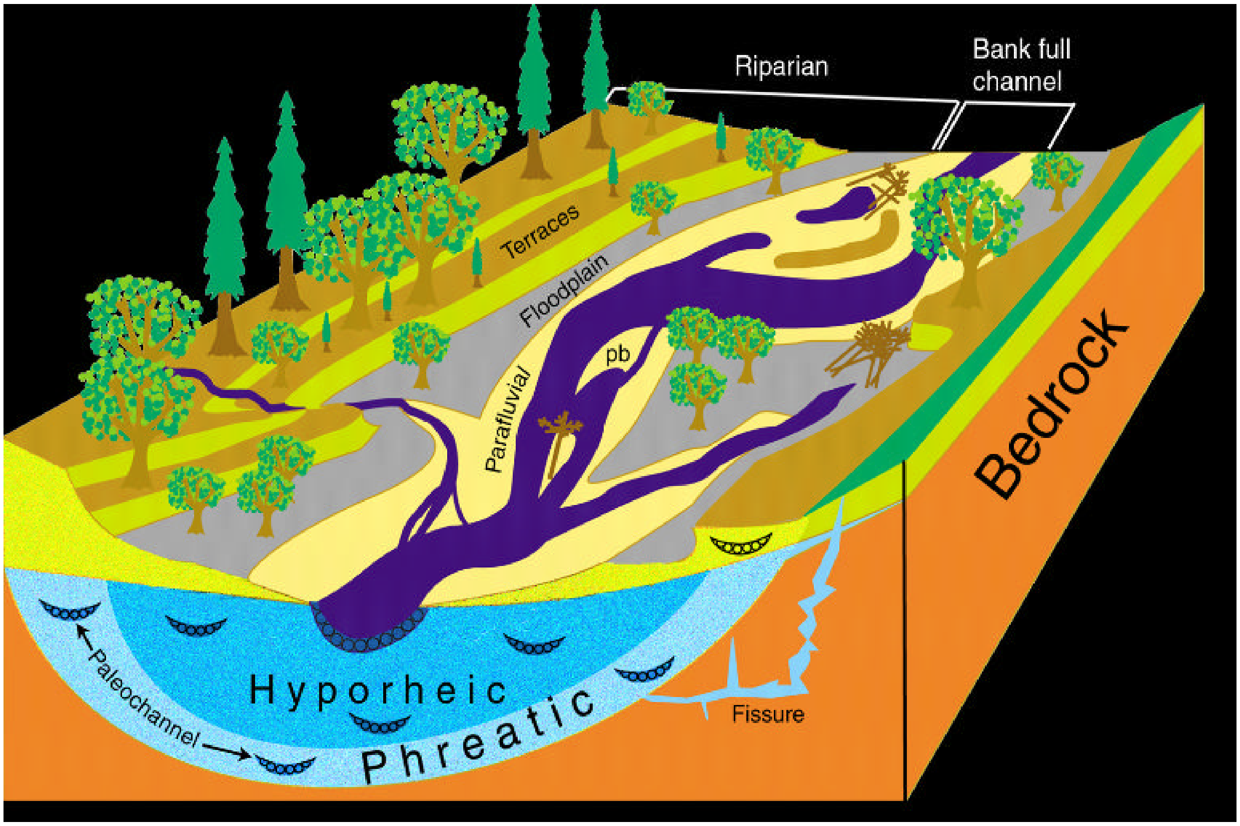

Figure 1. Three-dimensional illustration of gravel-bed river floodplains showing major surface features and the vertical and lateral extent of surface and ground water and spatial dimensions of the subsurface hyporheic zone (after Stanford 1998).

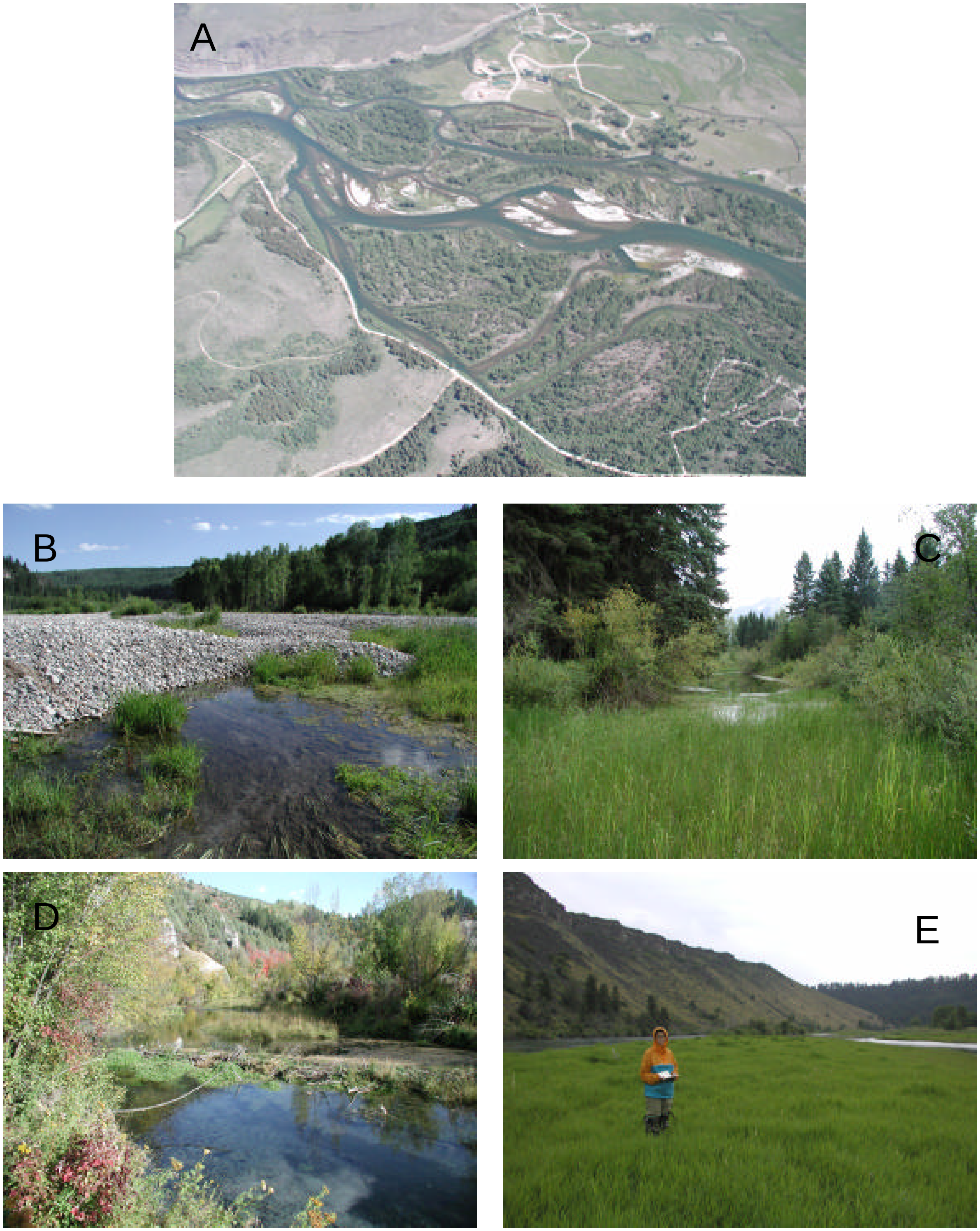

Figure 2. (A) aerial photo of the lower segment of the Swan Valley floodplain; (B) upwelling zone of groundwater through cobble bar; (C) is a backwater pond; (D) is a springbrook originating from hyporheic groundwater return flow; (E) is an island covered with vegetation.

ecosystems (Bradley et al. 1991, Braatne et al. 1996, Mahoney and Rood 1998, Rood et al. 1998). The primary causes of these declines have been impacts related to damming, water diversions and the clearing of floodplain habitats for agricultural use and livestock grazing (Braatne et al. 1996). Studies conducted in the 1990's on vegetation of the Snake River floodplains within our study area concluded that declines in riparian cottonwoods are related to the suppression of seedling recruitment (Merigliano 1996). Since cottonwoods are a relatively short-lived tree (100-200 years), declines in seedling recruitment over the past 50 years have lead to the widespread restructuring of the age structure of the communities to old individuals, which if left unchecked will eventually lead to loss of the riparian cottonwood ecosystems along the alluvial floodplain reaches of the Snake River in the study area.

Further examples of cut and fill alluviation and floodplain processes affecting the SHM is seen in the variation in thermal regime. While the change in temperature is particularly striking along the longitudinal gradient of a river (Hauer et al. 2000), there are surprising departures from this general pattern in which there may be extensive variation in temperature correlated with increased complexity of floodplain systems. Since the spatial dimension of the river landscape is three dimensional (see Figure 1 above), incorporating the river channel, surface riparian and hyporheic habitats into a river corridor as an integrated ecological unit, river floodplains are segments along the river corridor where not only is spatial complexity maximized; but also thermal complexity is maximized. This is very evident in comparing thermal regimes of the main channel with backwater or side channel habitats, but just as profound in its ecological implications in floodplain reaches affected by hyporheic return flows to the surface.

Recent study has shown that pond and springbrook habitats located on large river floodplains may have steep thermal gradients exceeding 10^{o}C over less than 2 m in vertical strata. Thus, thermal complexity, associated with spatial complexity on large river floodplains, provide an increased abundance of riverine habitats and regimes (Stanford 1998). Thus, the hydrologic and geomorphic processes that so profoundly affect the easily observed habitat mosaic of surface features on the floodplain are equally influential upon a subsurface habitat mosaic.

The three principal concepts to grasp that underpin this work are: 1) that the Shifting Habitat Mosaic of river floodplains is spatially and temporally dynamic, 2) that the SHM is the essential template that supports the biodiversity, complexity and production of the river system, and 3) the SHM is sustainable only through geomorphic change which is driven by river hydraulics. In other words, the SHM is driven by a dynamic process that may be fast or slow and results in biotic responses that reflect the temporal and spatial heterogeneity that is a legacy of past geomorphic work and change. A fundamental feature of the SHM is that it principally functions at the landscape spatial scale and is profoundly influenced by the frequency and intensity of flooding and the ability of the river "to do work" through the processes of cut and fill alluviation. Finally, these three principle concepts are not solely affected in the Snake River study area by hydrologic patterns and regimes under the control of the Reclamation and Palisades Dam Operations. The US Army Corps of Engineers (CoE) also plays at least two very important roles that directly affect the SHM. a) The CoE is responsible for flood control throughout the Columbia River Basin and thus greatly influence dam withdrawal schedules during snowmelt, and b) through the Section 404 permitting and regulatory process affect floodplain levee and river bank hardening. Indeed, floodplains may be dramatically constrained by encroachment from levee systems that limit the extent of flooding and natural geomorphic processes.

Ecologically Based Systems Management – Research Objectives

The overarching objective of an Ecologically Based Systems Management information system is to provide managers with the fundamental knowledge and data necessary to engage the physical, biogeochemical, and biological components that result in the long term sustainability and ecological integrity of the river and the native flora and fauna. Within the context of these EBSM objectives, we organized the research to address a series of research questions. Questions were based on the literature, our experience in river ecology and understanding the Shifting Habitat Mosaic, and on how the SHM may be affected by regulation of river discharge by Palisades Dam Operations.

Specific questions addressed:

- What discharge volumes and regimes are necessary to produce sufficient power to realize cut and fill alluviation and sustain the geomorphic template of the SHM over time? Can these be achieved within the constraints of climatic water supply? Are these attainable and still meet the contractual obligations of the Reclamation and the Palisades project?
- What discharge regimes optimize the regeneration of cottonwood? Can these be achieved within the operational constraints of current operations? How might these be modified?
- What are the ranges of historic winter flows? How might these be coordinated with over-winter fish habitats to optimize native species?
- What discharge volumes and regimes are necessary during late summer and fall to sustain the regeneration of the cottonwood gallery forest and optimize variation of river habitats for the native fish and other aquatic species? Are these regimes attainable and still able to meet the contractual obligations of the Reclamation and the Palisades project?

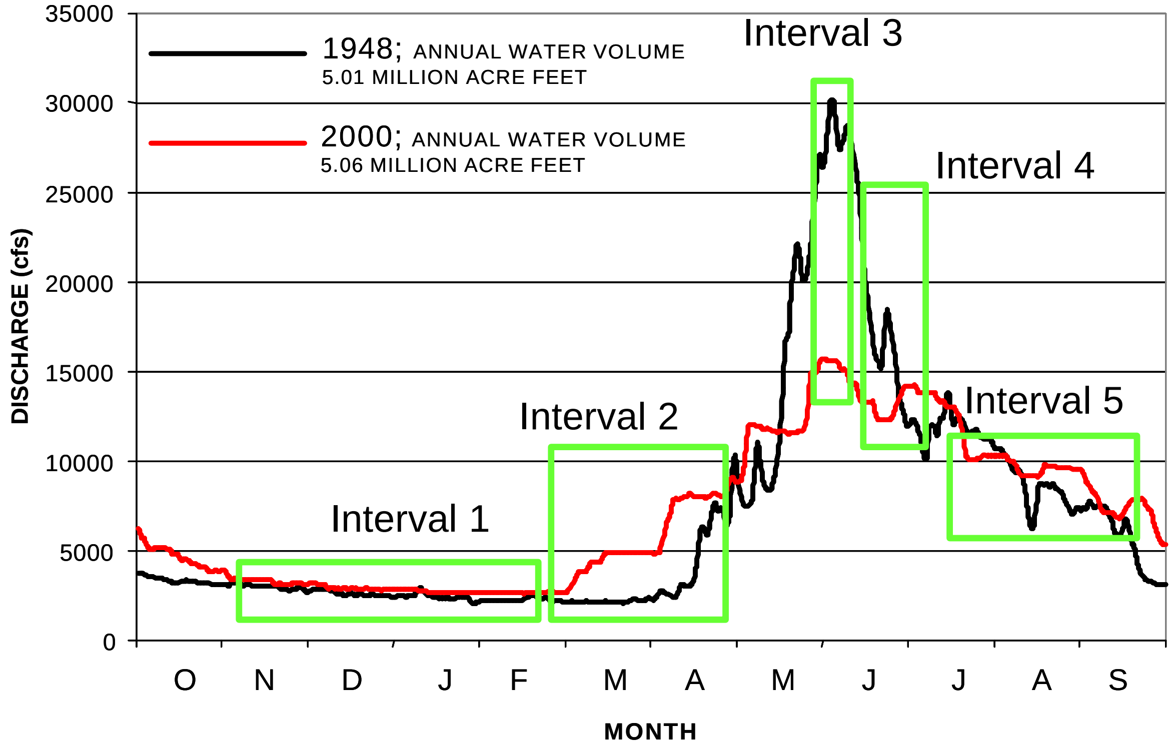

Figure 3. Two hydrographs of average water years over the period of record from 1911 to 2002. 1948 is representative of pre-dam hydrograph regime. 2000 is representative of post-dam hydrographic regime. Both years had approximately the same total water volume discharged from the Snake River at Heise. Temporal intervals 1-5 are explained in text.

Each of these research objectives and the questions that are derived above are illustrated here distributed across both a typical water year discharge regime from before and after Palisades dam construction and operations (Figure 3). The water years illustrated here are daily mean discharges for water years 1948 and 2000. (Note that in the US, water years begin on October 1 of the preceding year and end September 30 of the expressed year.)

There are five primary time intervals distributed throughout the water year that have very specific ecologically-based constraints. Interval 1 is directed toward winter flows and the habitats, particularly fish habitat that would favor native Yellowstone cutthroat trout over non-native rainbow trout or other non-natives. This issue also directly affects storage of water in Palisades reservoir. Interval 2 affects the initiation of spring snowmelt flows. In high discharge volume water years as illustrated in Figure 3, discharge has often been increased early in post-dam years to release stored water in Palisades reservoir in preparation of capturing the snowmelt and to reduce the risk of flooding. This directly affects aquatic habitats, fish life histories and the ability of fishes to physiologically respond to the increased discharge during a time interval that is not natural. Interval 3 is directed toward maximum discharges historically associated with spring snowmelt and the power that is generated by the river to do geomorphic work. We know that this is essential to the long term sustainability of the Shifting Habitat Mosaic and is a fundamental feature in the analysis below. Interval 4 affects the rate of the declining hydrograph after the spring snowmelt. The rate of the decline in the falling limb of the hydrograph (sometimes referred to as a ramping rate), directly affects the regeneration and sustainability of the cottonwood gallery forest. It also affects the rate of change in fish habitat. Interval 5 focuses on the summer flow duration, the rate of water table decline and also affects the contractual obligations and the operation of Palisades Dam and the supply of irrigation water.